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Diseases in Southeastern Forest Nurseries and their control

by

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COVER PHOTO:

The Little River Nursery of the North Carolina State Division of Forestry at Goldsboro. Its fumigated beds produce uniform, healthy stock.

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INTRODUCTION

The large increase in planting forest trees in the United States during the last 10 years has resulted in a tremendous increase in the demand for planting stock. This demand has been exceptionally heavy in the South, where favorable growing conditions and the use of fast-growing species have made forest farming a profitable business. Seedling production in southern nurseries increased from 400 million in 1955 to more than a billion in 1959. Although the closing of the Soil Bank Program has curtailed production considerably, seedling demand during the next few years is expected to remain high since thousands of acres of land still need restocking.

The increased production of seedlings, often accomplished by increasing the seedling density on existing nurseries, brought about a new awareness of disease problems. Now that production has been lowered somewhat, losses from diseases, insects, and poor agronomic practices must be kept as low as possible to keep down the price per thousand seedlings.

This handbook gives descriptions and control of the more common diseases of seedlings of forest trees occurring in southern nurseries. It is divided into four major parts: (1) disease descriptions and specific control measures, (2) general methods and techniques involved in controlling the diseases, (3) list of chemicals and formulations used to control the diseases, and (4) names and addresses of chemical manufacturers.

Damping-off

Damping-off is probably the most widespread disease of forest tree nursery stock and occurs to some degree in almost all nurseries. It is primarily a disease of coniferous seedlings, although many hardwood species may be affected.

Numerous fungi may cause damping-off. *Fusarium* spp. appear to be most commonly associated with this disease in southern nurseries. Other fungi, especially *Rhizoctonia solani* on yellow-poplar and *Pythium* spp. on longleaf pine, may also cause heavy losses.

The term damping-off describes a group of symptoms rather than one particular disease. Three kinds of damping-off are generally recognized. In *pre-emergence* damping-off, the seed itself is decayed or the seedling is killed before it emerges from the soil. Often this loss is blamed on poor seed, since it is difficult to determine whether or not the seeds were viable if the seedlings did not emerge. The presence of germinated seed with decayed radicles is a good indication of *pre-emergence* damping-off.

In *post-emergence* damping-off, the seedlings are affected after they appear above the ground. In most instances, they are attacked at or slightly above the soil line. The first symptom is a brown lesion at the root collar. The stem at this point is rapidly girdled and the infected seedling topples over. This type of damping-off is sometimes confused with heat lesions, which usually appear $\frac{1}{2}$ to 1 inch above the ground line and are whitish in color, compared to the brownish decayed tissue at the ground line in the case of damping-off.

During long periods of high humidity, some fungi may attack the tops of seedlings, resulting in what is termed *top damping-off*. In many such instances, the roots are not affected.

The fungi that cause damping-off are, for the most part, common soil inhabitants and are able to survive in the soil in the absence of a host plant. They do not usually cause disease unless conditions for their development are favorable or conditions for the growth of seedlings are poor. Consequently, damping-off can usually be kept to a low level by manipulating the environmental conditions in which the seedlings are growing. The following practices are recommended for keeping losses from damping-off to a minimum:

1. Choose a well-drained site for the nursery.
2. Plant after soil temperature is above 60° F.
3. Keep soil pH level at 6.0 or below.
4. Avoid dense stands.
5. Maintain a low level of nitrogen until the seedlings are beyond the damping-off stage (usually about 6 weeks old).
6. Turn under cover crops at least 2 months before seeding.
7. Use only enough mulch to conserve moisture.

In most cases damping-off in southern forest nurseries makes its appearance and runs its course in a very short time. For this reason, there is rarely much to be gained by attempts at chemical control once the disease is discovered. Several fungicides such as Thiram,[1] Captan, or PCNB can be drenched into the soil, but the effects of these treatments are only temporary, and their effectiveness questionable when applied after the disease appears. Where damping-off is causing losses consistently over a period of years, treating the seed with Thiram will lower the incidence of the disease. Seed treatments, however, usually lower germination from 5 to 15 percent. Damping-off can also be controlled effectively by the use of preplant soil fumigation with an all-purpose soil fumigant, but the expense is hardly warranted unless other problems such as weeds, root-rot, or nematodes are causing considerable injury, and the cost of treatment can thus be prorated over multiple benefits.

Root-Rot

Like the term damping-off, root-rot is a general term rather than a distinct disease. Root-rots can be caused by a number of different fungi. In many instances, fungi that cause damping-off will continue to be active after the seedlings have developed stiff stems and cause death of the seedlings. Such damage is usually referred to as late damping-off or early root-rot. In general, small roots are the first to be attacked by root-rot fungi. The first noticeable symptom is a blackening or reddening of the infected roots. These roots die, and in severe cases, the disease progresses to include the larger roots. Top symptoms are not always correlated with degree of root damage because seedlings in the nursery are usually not under any stress for water or nutrients. A large portion of the roots may be destroyed before any stunting or chlorosis of the tops is observed. When put under stress in the outplanting site, however, badly root-rotted seedlings do not survive.

Root rots generally become increasingly severe over a period of years, especially when several successive crops are grown on the same area. Their development is often so slow that the gradual decline in the quality of the seedlings is scarcely noticeable, especially if the disease occurs throughout the nursery. In such a case, the disease can only be detected by careful removal of the seedlings from the soil and examination of the root systems. Fumigation of small plots with an all-purpose soil fumigant and comparison of seedlings from the fumigated and non-fumigated soil is a good method to use in detecting damage caused by root rots.

One of the most serious and distinctive root rots which occur in southern nurseries is known as black root-rot. It has been identified from at least 10 southern nurseries and may occur in more. All species of southern pine are susceptible. In the early stages, it is impossible to distinguish from other root rots. Later, however, characteristic reddish-black swellings may be noted on the taproot and larger laterals. These swellings may be localized or in severe cases cover the entire taproot. The disease is most severe

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[1] The mention of trade products does not imply endorsement by the U. S. Department of Agriculture over similar products not named.

during periods of high temperature. In early fall, numerous new roots appear just below the ground line. These roots may help the seedlings survive during the fall "hardening-off" period, but survival of these seedlings in the field is often poor. Black root-rot is caused by a complex of organisms, the most important of which are Sclerotium bataticola and Fusarium spp. Although nematodes are also believed to be a part of the complex, their role has not been determined.

Other damaging root rots that occur in southern forest nurseries are: Cylindrocladium scoparium on white pine, yellow-poplar, and Fraser fir; Pythium sp. on longleaf pine; Phytophthora cinnamomi on black walnut and yellow-poplar; and Rhizoctonia solani on yellow-poplar.

Preplant fumigation with a complete soil fumigant is the best control for root rots. Drenching with fungicides is impractical over a large area and, at best, gives only temporary control of the disease.

Nematodes

Nematodes are microscopic eel-shaped animals which feed on the roots of plants. Like root rots, nematodes seldom cause spectacular losses, but often become increasingly severe over a period of time. Often the increase in population of parasitic nematodes is so gradual that the damage they cause is not easily noticeable. However, they can cause severe damage, especially to small seedlings.

The typical symptoms of nematode injury are a general decline, stunting, and chlorosis of the seedlings. The brilliant yellow color of affected seedlings is very distinctive and easy to distinguish from the light yellow-green color of nitrogen-deficient seedlings, and the creamy-white color of those that are iron-deficient. Nematode injury may be scattered among the seedbeds, but more often is confined to localized spots. The small rootlets of the seedlings usually become necrotic. On very small seedlings, the roots may look as though they had been clipped off, and have small rounded knobs on the ends of the roots. On hardwood seedlings, the root knot nematode may cause swellings all along the roots.

Damage to the roots by the feeding of nematodes often results in attack by soil fungi. The resulting root-rot and nematode complex may cause considerable damage.

Since nematodes are usually microscopic in size, it is impossible to diagnose nematode injury without special techniques and a knowledge of the nematodes themselves. For this reason, soil and root samples must be sent to someone with facilities to make determinations for the presence of nematodes. Some state universities have such facilities. Soil samples should be taken from the root zone of seedlings within the affected area, on the margin of the affected area, and in adjacent healthy areas. These samples should be collected in much the same way that soil samples are taken for fertilization recommendations; that is, several small samples should be taken at random

in the collecting area, pooled and mixed thoroughly. At least a 1-pint subsample is then drawn and placed in a plastic bag for shipment. Root specimens should also be placed in plastic bags.

There are several fumigants available for the specific control of nematodes. The most common are dichloropropane-dichloropropene (DD), ethylene dibromide (EDB), and 1,2-dibromo-2-chloropropane (DBCP). DD and EDB must be used as preplant treatments with effective rates of 25 gallons and 15 gallons per acre, respectively. DBCP is the only material that can be used on living seedlings, but must be used only in the diluted form, since the concentrate is toxic to seedlings. Four to six gallons per acre usually give good control.

All-purpose soil fumigants will also control nematodes, but if nematodes are the only problem, a simple nematocide is more economical to use.

Cylindrocladium Blight

Cylindrocladium blight, caused by *C. scoparium*, is the most important seedling disease of white pine. This fungus may cause damping-off, root-rot, needle blight, and stem cankers, but the most spectacular and damaging aspects of the disease are the needle blight and stem cankers of 2-0 seedlings. Needle blight usually appears during middle or late summer. Initial infection takes place near the tip and progresses toward the base of the needle. The first symptom is yellowing of infected tissue, but the color rapidly changes to a brick red. Severely affected beds appear as if they have been scorched by fire. The dead needles are usually shed during fall and winter. The buds are not usually affected, and if no stem cankers occur, the seedlings will put out new needles the next spring and resume growth.

Stem canker is the most serious aspect of this disease. Cankers may occur at any point on the stem, but usually originate at the base of needle fascicles. The first symptoms are brownish areas which gradually enlarge and become slightly sunken. In some instances, the canker may be walled off by callus growth; more frequently, however, the canker enlarges until the stem is girdled. The entire plant then takes on the brick-red color which is characteristic of the needle blight phase and finally dies. The needle blight phase of Cylindrocladium blight is sometimes confused with a needle cast caused by an unidentified fungus. The needle cast symptoms usually become apparent in September or October, much later than those of Cylindrocladium. The needle cast fungus affects only the needles. Other than the time of appearance, the only way to distinguish the two diseases is by isolating the causal fungi.

Control of Cylindrocladium blight is very difficult. The fungus is soilborne and produces a stage resistant to normal rates of methyl bromide. At least 500 pounds per acre and sometimes more are required to give adequate control. The needle blight phase of the disease can be kept in check by using ferbam at the rate of 2 pounds per acre in a regular spray schedule. The spray should be applied at a high pressure in order to insure adequate needle coverage. Stem cankers are more difficult to control because the dense

needles of 2-0 seedlings prevent adequate coverage of the stem. Hence it may be advantageous to increase the volume to 300 to 400 gallons per acre so that the excess spray will run down the stems of the seedlings. The same spray schedule will also control the needle cast disease.

Fusiform Rust

Fusiform rust, caused by the fungus Cronartium fusiforme, is potentially the most serious disease of pine seedlings in southern forest nurseries. Although infected seedlings rarely if ever die in the nursery, they survive only a short time after being outplanted.

The early symptoms of fusiform rust are very difficult to detect. They consist of tiny purple spots on the needles or stems of small seedlings. The typical spindle-shaped gall or swelling on the stem of the seedling is usually not evident until late summer. These galls are found normally near the ground line, but occasionally occur up to six inches high on the stem when late infection takes place. In some instances, galls may not be produced on infected seedlings until late the following spring, hence making it impossible to remove all infected seedlings shipped from the nursery during fall and winter. Excessive basal branches are sometimes indicative of infection by fusiform rust, but this is not a reliable characteristic in diagnosing this disease.

The fungus which causes fusiform rust requires oak, as well as pine, to complete its life cycle. Water oak and several species of the red oak group are the most susceptible and most common alternate hosts. Oak leaves are infected by spores produced on infected pine in the spring shortly after the oak leaves emerge. About 2 weeks later, spores are formed on the oak, which then infect pine. Pine seedlings are liable to infection immediately after they emerge from the soil until weather conditions become unfavorable for infection to take place, usually in June.

Weather conditions greatly influence infection of pine by the fusiform rust fungus. Periods of 18 hours or more of saturated atmosphere and temperatures between 60° and 80° F. are necessary for the abundant infection of pine seedlings. Since these conditions seldom occur after July 1, seedlings are relatively safe from infection after that time, and spraying to control the disease can be terminated. Fusiform rust can be controlled to $\frac{1}{2}$ of 1 percent infection in the Southeast by weekly applications of ferbam at the rate of 2 pounds per 75 gallons of water per acre. During periods of rapid growth, however, applications should be made more frequently to keep the new growth protected.

Brown Spot

Brown spot is caused by the fungus Scirrhia acicola. Although this fungus is capable of causing a serious needle disease of large trees of loblolly and white pines, it is a problem in the nursery only on longleaf pine and occasionally slash pine.

The initial symptoms of brown spot are straw-colored spots on the needles. These spots later turn light brown and are bordered by deep brown zones which may become purple during cool weather. Another type of symptom known as "bar spot" initially appears as an amber-yellow band that encircles the needle. Later, a brown band may appear in the center of the yellow band. The fungus usually sporulates in the center of the spot or on dead portions of the needles.

Although brown spot may occur in the nursery as early as May or June, it is most serious in late summer and fall. In the states from Georgia northward, brown spot is seldom a serious problem in the nursery. The fungus can be easily controlled by periodic spraying with Bordeaux mixture. Since this disease continues to develop in the outplanting site, it is good practice to make the final spray application just before lifting.

Rhizoctonia Needle Blight

During extended periods of moist, cool weather, the Rhizoctonia fungus may cause top killing of many species of conifers. New growth is most susceptible to attack. The symptoms are almost identical to those caused by *Cylindrocladium scoparium* on white pine foliage. On longleaf pine the fungus first attacks the needles near the soil line and eventually moves into the bud and crown, causing death of the seedling. The mycelium of the fungus can be seen as fine brown threads. These are often numerous enough to mat the dead needles together.

For longleaf pine, the best control is to clip the needles. This permits good aeration and lowers humidity near the ground line, where the fungus is most active. Withholding irrigation may also help to keep the disease in check. Spraying with fungicides is usually not necessary. If needed, however, Terrachlor at the rate of 50 pounds per acre is the best to use. Spraying should be followed by at least $\frac{1}{2}$ inch of water.

Phomopsis Blight

Phomopsis blight, caused by the fungus *Phomopsis juniperovora*, is the most serious disease of eastern redcedar and Arizona cypress seedlings. The distinguishing symptom of the disease is the death of branch tips or sometimes the entire tops of the seedlings. The fruiting bodies of the fungus appear as numerous small, black spots on recently killed needle or stem tissue. During moist periods, the spores are extruded from the fruiting body and are spread to nearby plants by splashing rain or irrigation water.

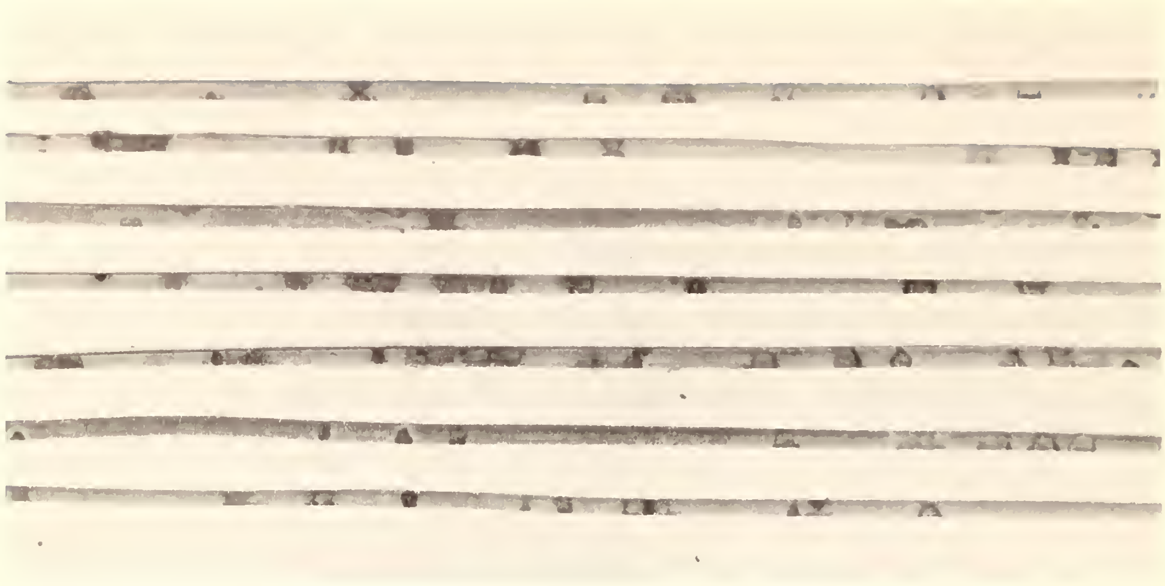
Fungicides containing mercury appear to be the most effective in controlling Phomopsis blight. The most commonly used formulations are Puritized Agricultural Spray and Merbam. Under southern conditions, Merbam appears to be the most effective. Sprays should be applied every 7 to 10 days throughout the growing season. During periods of moist, cool weather, twice-weekly applications may be necessary.

Fusiform rust swellings near ground line of 1-0 loblolly pine seedlings.

Left, seedling stunted by black root-rot. Center, seedling with healthy roots. Right, seedling almost denuded of roots by black root-rot, with the additional roughened root swelling characteristic of this root-rot.

Slash pine beds in a southeastern nursery. The foreground of the three central beds was not fumigated, since the plastic covers did not quite cover these beds entirely. The remainder of these beds was fumigated with Brozone. Note the difference in size, quality, and uniformity of seedlings following fumigation.

Loblolly pine seedlings from nursery beds given soil treatments as indicated. Each bundle contains 25 seedlings pulled at random from a given bed.



Brown spot lesions on longleaf pine needles. These are sometimes called bar-spots.

Slash pine seedlings. Left, roots destroyed entirely by the stunt nematode, *Tylenchorhynchus claytoni*; center, roots partially destroyed by this nematode; right, a healthy seedling.

Telia of fusiform rust on a water oak leaf. These hairlike structures on the under side of oak leaves produce the spores that infect pines. In this stage, fusiform rust cannot be separated easily from several other rust fungi.

It is important to cull all infected seedlings at lifting, since seedlings with only a single infected branchlet have little chance of survival after transplanting. There is also the possibility of spreading the fungus to other seedlings in the shipping bundle.

Cercospora Blight

A new disease of redcedar caused by Cercospora sequoiae has been noted in several forest nurseries. The distinguishing symptom of the disease is a gradual browning of the needles starting on the oldest needles on the lower branches and gradually spreading upward and outward. In advanced stages, only the tips of the seedlings remain green. This disease is easily distinguished from Phomopsis blight, which results in the death of the branch tip.

Although this disease has not been noted on Arizona cypress seedlings in the nursery, it is known to cause a serious needle blight disease of Arizona cypress in plantations. All cypress used as windbreaks around nurseries should be examined for this disease and all infected plants removed or sprayed. The most effective fungicide for use against this disease is Bordeaux mixture. Seedlings should be sprayed at 7 to 10-day intervals once the disease is determined to be present, or where it recurs frequently this spray schedule can be made standard practice, starting June 1.

Chlorosis

Chlorosis is a general term denoting a yellow color of the foliage. Two general types of chlorosis may be found in the nursery. The commonest type involves general pale yellowing of all the needles of the seedling; this type results from nitrogen deficiency. Application of ammonium nitrate or some other nitrogen source will usually correct this condition. The rate and number of applications will depend upon many diverse soil and other factors, but 25 to 50 pounds actual nitrogen per acre per application is usually sufficient.

Another type of chlorosis often seen in nurseries is characterized by a creamy-white color of the new needles, while the older needles retain a normal green color. In severe cases, however, some of the older needles may also become chlorotic. The most common cause of this type of chlorosis is iron deficiency. This does not necessarily imply a deficiency of iron in the soil. The problem is one of availability of iron to the plant. Many factors affect utilization of iron in the soil by the seedlings, one of the most important of which is soil pH. Most nurseries have small localized areas in which seedlings appear chlorotic every year. Such areas usually have a soil pH of 7 or above. Application of acid-forming fertilizers such as ammonium or ferrous sulfate will lower the pH.

Low soil pH (below 5.0) coupled with high phosphate content sometimes results in binding the iron in an insoluble iron-phosphate complex. Raising the pH with lime will often remedy this situation.

Where iron deficiency is a problem, the use of iron chelate is the fastest way to correct chlorosis. Application of 3 pounds actual iron per acre is usually sufficient. Where more iron is needed, it is best to make frequent applications rather than increasing the amount at any one application.

In addition to nitrogen and iron deficiency, chlorosis can be caused by hot weather, root diseases, chemical injury, or other factors.

Since it is often difficult to determine the exact cause of chlorosis, the control must be attempted on a trial-and-error basis.

Chlorotic seedlings are very sensitive to injury by mineral spirits. If chlorosis is widespread in the nursery, the rate of mineral spirits used for weed control should be decreased or the spraying terminated until the seedlings return to their normal color.

Sand Splash

Sand splash is caused by rain or irrigation water splashing soil on the needles and stems of seedlings. If the soil is high in silt or clay content, soil particles will adhere tightly to the seedling. Continued splashing may build up a coat of soil $\frac{1}{4}$ inch or more thick on the seedling; then the layer of sand can cut down photosynthetic area and reduce growth. The most damage, however, is caused by pathogenic fungi which are splashed up with the sand and kill needles or sometimes the entire seedling.

The best control for sand splash is an adequate mulch to reduce splashing. A soft rake or flap may be pulled over the beds to dislodge the sand.

Thelephora Terrestris

Thelephora terrestris is one of the most common fungi seen in the nursery. The small, purple, shelf-shaped or funnel-shaped fruiting bodies can be found attached to seedlings and debris or on the ground. Although the fungus often uses seedlings for support of the fruiting body, little if any damage is done to the seedling. There is no need to control the fungus.

Foliage Application of Fungicides

Control of diseases such as fusiform rust, Phomopsis blight, and brown spot in forest nurseries is done by periodic spraying with fungicides. Adequate control of these and other foliage diseases is dependent upon application of the correct fungicide in the correct amount at the correct time. All fungicides presently used in forest nurseries act only as protectants and not as eradicants. For this reason, it is imperative that the fungicide be applied to the foliage before the fungus has a chance to penetrate the plant tissue.

The foliage must be uniformly covered with the fungicides. To accomplish this, it is necessary to disperse the liquid into very small droplets. In most nurseries, this is accomplished by passing the liquid through small holes (1/32 inch or less in diameter) at a pressure of at least 300 pounds per square inch. Even finer droplet size can be obtained by the use of a mist blower and this has an added advantage in utilizing a smaller volume of water; hence, more beds can be sprayed at one passing. Both of these factors are important when attempting to cover the nursery in the shortest time possible.

Calibration and adjustment of the sprayer are also important in obtaining a uniform coverage. The spacing of the nozzles on the spray boom and the height of the nozzles above the seedlings are largely determined by the type of nozzles used. The spray stream from each nozzle should overlap slightly near the top of the seedlings. Since the amount of spray applied is dependent upon the orifice size of the nozzle, pressure, and speed of the tractor, it is important that the sprayer be carefully calibrated at the beginning of each season and then checked at periodic intervals. Seventy-five to 100 gallons of water per acre with a pressure sprayer, and 25 to 30 gallons per acre with a mist blower will give good coverage.

Because of the layer of waxy substances covering the surface of conifer needles, and to a lesser degree hardwood leaves, spray droplets do not flatten out to give complete coverage when they fall on the plant. To remedy this, materials may be added to the spray solution in order to lower the surface tension and allow the spray droplets to flatten. These surfactants or "spreaders" are usually combined with "stickers" which cause the fungicide to adhere to the foliage and thus resist removal by rain or irrigation water. Some fungicide mixtures contain spreader-stickers when they are purchased; most do not, however. Several good spreader-stickers are on the market. These should be added to the spray solution as it is mixed.

The number and frequency of applications are dependent upon the disease being controlled, weather conditions, and rate of growth of the seedlings. Except under conditions of high rainfall, most fungicides will remain effective on the foliage for 10 to 14 days. During periods of rapid growth, the interval between successive applications should be shortened in order to provide coverage of unprotected new growth. During such periods, sprays should be applied at 5 to 7 day intervals.

A knowledge of the disease is very important in determining when and how often to spray. Sprays to control fusiform rust must be applied from the time the seedling emerges to about July 1, when weather conditions are unfavorable for further infection. Phomopsis blight, on the other hand, does not appear until about June but may be active until October. In general, foliage diseases require periods of high humidity for optimum spread and infection. Because of this, it is wise to make an extra spray application immediately following a wet period. If the forecast is for several days of wet weather, it is better to make the application beforehand.

Drenches

Drenching is the application of chemicals to the soil with the use of large amounts of water. For the most part, drenches are used around living plants. They are aimed primarily at preventing enlargement or intensification of an existing infection, and not eradication of a disease.

Unlike the soil fumigants, which move through the soil mostly as gas, chemicals used for drenches usually have a low volatility. For this reason, enough water must be added following application to move the chemical down into the root zone. For small areas the chemical can be put on with a hand sprayer or a sprinkling can. The remainder of the water can be added through the irrigation system. About 3/4 inch of water will distribute the chemical through the upper 6 inches of soil. For large areas, the material can be applied with a power sprayer or through the irrigation system. Drenching of large areas is often prohibitive in cost.

Drenching is at best only a temporary control. Most chemicals used for drenching are rapidly inactivated in the soil or may be leached out. For persistent trouble spots involving soil organisms, an eradicant treatment with an all-purpose soil fumigant should be used.

Soil Fumigation

Soil fumigation is a process in which a volatile organic chemical is introduced into the soil with the subsequent release of toxic vapors. Some of these chemicals can be classified as all-purpose soil fumigants and will effectively control all groups of soil microorganisms as well as weeds. Others are more specific and will control only nematodes. There are no fumigants that are specific for fungi alone. The success of soil fumigation depends largely upon the following soil conditions:

1. Soil temperature. Soil fumigants are most effective at temperatures between 50° and 80° F. In general, the lower the temperature, the longer it takes to get complete fumigation and for the fumigant to escape from the soil after the fumigation period is over.

2. Soil moisture. The optimum soil moisture level for most effective fumigation is at or near field capacity, which approximates the optimum moisture level for planting. High moisture levels result in a poor job of fumigation and a slow escape of the fumigant from the soil.

3. Soil tilth. Since most fumigants move through the soil in the gaseous state, it is important that the soil be in good tilth. Disking or plowing to 6 or 8 inches should be done immediately before fumigation. Plowing following completion of the fumigation period will aid in the escape of the fumigant from the soil.

4. Soil texture and organic matter. Most recommendations for soil fumigants are based on light-textured soil with relatively little organic matter. On heavy soils, or those with a high organic matter content, the rate of application should be increased by 25 to 50 percent. The waiting period before planting should also be increased. Cover crops should be turned under at least 2 months before fumigation.

In addition to the increased growth of seedlings attributable to the control of disease organisms and weeds, general soil fumigants appear to stimulate the growth of seedlings. In soils of high fertility, the stimulation sometimes results in seedlings that grow too large. When this happens, some modification should be made in the fertilization or irrigation program.

Some of the more specific properties and techniques of application of the more commonly used soil fumigants are given below.

Methyl bromide is usually sold as a mixture containing 98 percent methyl bromide and 2 percent chloropicrin, the latter acting as a tear-gas warning for the presence of the odorless methyl bromide. It is available in the commonly used 1-pound cans or large cylinders.

The standard procedure for the use of this chemical is to release it beneath a gasproof cover, usually a 4-mil thick polyethylene sheet approximately 100 x 20 feet in size. The cover is supported on sacks of straw, the edges are sealed with soil, and the methyl bromide released by means of special applicators.

Another technique for application of methyl bromide is the injection of a mixture of methyl bromide and a solvent such as Varsol 6 to 8 inches into the soil by the use of a special apparatus. The treated area is then covered with a polyethylene cover. The major advantages of this method are that larger covers can be used and no support is needed since more efficient utilization is obtained by injection. On most soils, 250 pounds per acre actual methyl bromide is sufficient.

A third method for the application of methyl bromide involves the use of a special device which lays the polyethylene cover and seals the edges. Methyl bromide, vaporized by passage through a hot-water bath, is released through two hoses trailing beneath the cover. At present, only relatively narrow covers (6 to 8 feet) can be used with this method. Since the complete treatment of an area with this machine would require considerable overlapping of treated area, its use in forest nurseries would probably be limited to treatment of individual beds.

Regardless of the fumigation method used, the covers can be removed 24 to 48 hours after treatment, depending upon the soil type and temperature. Planting can be done 48 hours after the cover is removed.

The cost of methyl bromide fumigation depends upon application method used, the amount of fumigant, size of area, and proficiency of the fumigation crew. In general, the cost averages $350 to $500 per acre. Compared to the total value of the seedlings produced, this is a small price to pay for the insurance of producing a quality crop of seedlings. At $400 per acre, an average increase of only $3\frac{1}{2}$ seedlings per square foot will completely pay for the cost of fumigation in one season. There is good evidence, however, that fumigation will give good control of root diseases for 3 to 4 years, thus bringing the cost per year down to approximately $100 per acre. Fumigation also gives good weed control for one or more years.

<u>Vapam</u> or <u>VPM</u> has been widely used as an experimental general soil fumigant in forest nurseries, but only with little success because of ineffective methods of application. This material has been applied in several ways, most of which involve injecting the material into the soil or putting it through the irrigation system. The surface of the soil is packed with a heavy roller or irrigated with about 3/4 inch of water in an attempt to form a seal to prevent the escape of the gas. Recent work has shown that injection of the material into the soil at the rate of 50 gallons per acre (one-half the rate usually recommended for Vapam) and covering with a polyethylene cover for 48 hours gave consistent results comparable to methyl bromide. The total cost of this operation is about the same or less than methyl bromide. The major disadvantage is that planting cannot be done for 2 weeks after the cover is removed. The soil should be disked at least once before planting to facilitate escape of the chemical from the soil after removal of covers.

<u>Mylone</u> is another general soil fumigant that has been widely tested in forest nurseries. It is available as an 85 percent wettable powder that can be applied to the soil surface with a sprayer or as a dry powder which can be applied with a fertilizer spreader. The usual rate of application is 200 to 300 pounds per acre. After application, it is disked or rototilled to a depth of 6 to 8 inches. No cover or seal is required. A 2 to 3-week waiting period is required before planting. It is comparable in cost to methyl bromide, but has not so far given consistently good results.

Ethylene Dibromide (EDB) at recommended dosages is effective only against nematodes, and has no effect on fungi or weed seeds. It is injected into the soil at the rate of 10 to 15 gallons per acre of the 85 percent material. No surface seal is necessary. A waiting period of at least 2 weeks is necessary before planting.

Dichloropropane-dichloropropene mixture (DD) is injected into the soil in the same manner as EDB. At the recommended rate of 20 to 25 gallons per acre, it is effective only against nematodes. Rates of 100 gallons or more per acre have been reported to give weed control and possibly control of root disease fungi. A waiting period of 2 to 3 weeks is necessary before planting.

DBCP is available in both the granular or liquid form. The liquid form is applied in much the same way as EDB and DD. The granular form is spread with a fertilizer distributor and disked in. No surface seal is necessary. A waiting period of 2 to 3 weeks is necessary before planting. The recommended dosage is 20 to 35 pounds active ingredient per acre.

Like DD and EDB, DBCP is effective only against nematodes. It has one additional advantage over EDB and DD in that it can be used as a drench on living seedlings. Application of this material through the irrigation system has proven very effective. Four gallons of the active ingredient is mixed with about 100 gallons of water and injected into the irrigation system. An additional $\frac{1}{2}$ to $\frac{3}{4}$ inch of water is then used to distribute the chemical in the root zone. The undiluted material is highly toxic to seedlings and should never be used.

Other fumigants could be mentioned in connection with disease control, but they are not discussed because they have been inadequately tested in southern forest nurseries, or are not readily available, or have some marked disadvantages.

CHEMICAL FORMULATIONS AND APPLICATION RATES

Chemical	Manufacturer	Formulation	Rate per acre [1]	Method of application	Disease controlled
Bordeaux mixture		8-8-100	100 gal.	Spray	Brown spot, Cercospora blight
Captan				Drench	Damping-off
Captan 50-W	Stauffer	[2] 50% WP	4 lbs.		
Orthocide 50	Cal. Spray	50% WP	4 lbs.		
DBCP				Preplant fumigation	Nematodes
Fumazone	Dow	70% E	2 gal.		
Nemagon	Shell	50% E	2 gal.		
		10% G	175 lbs.		
		30% G	60 lbs.		
Fumazone		70% E	4 gal.	Post-plant drench	Nematodes
Nemagon		50% E	4 gal.		
Ethylene dibromide				Preplant fumigation	Nematodes
Dowfume W-40	Dow	40% S	22 gal.		
Dowfume W-85	Dow	75% S	10 gal.		
Soilfume 40	Niagara	40% S	22 gal.		
Soilfume 85	Niagara	85% S	10 gal.		
Ferbam				Spray	Fusiform rust, Cylindrocladium blight
Fermate	DuPont	76% WP	2 lbs.		
Ferradow	Dow	76% WP	2 lbs.		
NuLeaf	Cal. Spray	76% WP	2 lbs.		
Karbam Black	Sherwin-Williams	76% WP	2 lbs.		
Iron chelate				Spray	Iron chlorosis
Sequestrene 138 Fe	Geigy	6% WP	50 lbs.		
Sequestrene Na Fe	Geigy	12% WP	25 lbs.		
Versonol	Dow	9% WP	37 lbs.		
Methyl bromide				Preplant fumigation	Soil-borne diseases in general
MC 2	Dow	98% VL	300-400 lbs.		
Bedfume	Niagara	98% VL	300-400 lbs.		
Pestmaster	Michigan	98% VL	300-400 lbs.		
Methyl bromide	Kolker	98% VL	300-400 lbs.		
Brozone	Dow	70% in solvent	250-300 lbs. (actual methyl bromide)		
Merbam	Berk	10% WP	1½ lbs.	Spray	Phomopsis blight
Mylone	Union Carbide	85% WP	300 lbs.	Preplant fumigation	Soil-borne diseases in general
Puritized Agricultural Spray	Gallowhur	3% S	1 pt.	Spray	Phomopsis blight
Spreader-stickers			Use according to manufacturer's directions		
DuPont Spreader-Sticker	DuPont				
Ortho Spray Sticker	Cal. Spray				
Santomerse S	Monsanto				
Triton B 1956	Rohm & Haas				
PCNB				Spray	Damping-off, Rhizoctonia blight
Terrachlor	Olin Mathieson	75% WP	50 lbs.		
Thiram				Drench	Damping-off
Arasan 75	DuPont	75% WP	40 lbs.		
Tersan 75	DuPont	75% WP	40 lbs.		
Thiram 75W	U. S. Rubber	75% WP	40 lbs.		
Vapam				Preplant fumigation	Soil-borne diseases in general
Vapam	Stauffer	Liquid	50 gal.		
VPM	DuPont	Liquid	50 gal.		

1/ Based on chemicals as purchased.
2/ E = emulsion, WP = wettable powder, S = solution, G = granular, VL = volatile liquid.

ADDRESSES OF MANUFACTURERS OF CHEMICALS

F. W. Berk Company, Woodridge, New Jersey

California Spray-Chemical Corporation, Richmond, California

E. I. duPont de Nemours Company, Inc., Grasselli Chemicals Division, Wilmington, Delaware

Dow Chemical Corporation, Midland, Michigan

Gallowhur Chemical Corporation, North Water Street, Ossining, New York

Kolker Chemical Corporation, 600 Doremus Avenue, Newark 5, New Jersey

Olin Mathieson Chemical Corporation, Insecticide Sales Division, Baltimore 3, Maryland

Michigan Chemical Corporation, 500 North Bankston, St. Louis, Michigan

Monsanto Chemical Company, 710 N. 12th Boulevard, St. Louis, Missouri

Morton Chemical Company, Panogen Division, Woodstock, Illinois

Niagara Chemical Division, Food Machinery-Chemical Corporation, 100 Niagara Street, Middleport, New York

Rohm and Haas Company, 222 W. Washington Square, Philadelphia 5, Penna.

Shell Chemical Corporation, Agr. Chemical Division, 460 Park Avenue, New York 22, New York

Sherwin-Williams Company, 113 Guild Hall Building, Cleveland 1, Ohio

Stauffer Chemical Company, 380 Madison Avenue, New York 17, New York

Union Carbide Chemicals Company, 30 East 42nd Street, New York 17, New York

U. S. Rubber Company, Naugatuck Chemical Division, Naugatuck, Connecticut

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